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SMUTS OF GRAIN AND FORAGE CROPS IN KANSAS.

By L. E. Melchers.

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Summary Concerning Smuts.

Name of Disease.	Group. (See page 7)	Occurrence and location of the organism causing the disease.	Control measures.
Corn Smut.	1	Spores in the soil and manure, from smutted refuse.	No practical method of control. Seed treatment of no use. Rotate crops.
*Head Smut of the Sorghums.	1	Spores in the soil.	Seed treatment of no use. Remove and burn diseased plants. Rotate crops.
Kernel Smut of the Sorghums.	2	Spores lodged on the outside of the seed.	(1) Formaldehyde treatment: 1 pint to 30 gallons of water for 1 hour. (See page 34.) (2) Hot-water treatment: 134° to 140° for 12 minutes. (See page 34.)
Smut of Oats.	2	Spores lodged on the outside of the seed.	(1) Formaldehyde treatment: 1 pint to 45 gallons of water; sprinkle seed and allow to stand for two hours; or use dipping method; allow to stand for one-half hour. (See page 35.) (2) Hot-water treatment: 10 to 15 minutes at 132-133°. (See page 36.)
Stinking Smut of Wheat.	2	Spores lodged on the outside of the seed.	(1) Formaldehyde treatment: 1 pint to 45 gallons of water; using the sprinkling or immersion methods. Smut balls should be removed. (See page 35.) (2) Hot-water treatment: 10 to 15 minutes at 132-133°. (See page 35.) (3) Bluestone treatment. (See pages 33 and 35.
Kernel Smut of Millet.	2	Spores lodged on the outside of the seed.	(1) Formaldehyde treatment: 1 pint to 45 gallons of water for two hours, using the dipping method. (See page 36.) (2) Hot-water treatment: 10 to 15 minutes at 132-133°. (See page 37.)
Covered Smut of Barley.	2	Spores lodged on the outside of the seed.	(1) Long-time formaldehyde treatment: soak 2 hours in a solution, 1 pint of formaldehyde to 40 gallons of water. (See page 36.) (2) Hot-water treatment: 13 minutes at 126-129°. (See page 36.)
Loose Smut of Wheat.	3	The disease is *inside* the seed itself.	(1) Long-time hot-water treatment: soak 3 hours in water at 110-115° with frequent agitation. (See page 37.) (2) Modified hot-water treatment. (See page 33 and 37.)
Loose Smut of Barley.	3	The disease is *inside* the seed itself.	(1) Long-time formaldehyde treatment: soak 2 hours in a solution, 1 pint of formaldehyde to 40 gallons of water. (See page 37.) (2) Modified hot-water treatment. (See page 33 and 37.)

*This fungus may attack corn occasionally.

SMUTS OF GRAIN AND FORAGE CROPS IN KANSAS.

L. E. MELCHERS.

The most common and serious diseases affecting the grain and forage crops of Kansas are the so-called smuts. These diseases are more or less familiar to most farmers, since they occur in all parts of the state wherever such crops as wheat, barley, oats, corn, sorghum and millet are grown. Their importance in the regions where susceptible crops are raised is not generally known, but the loss sustained is enormous when carefully estimated. Collectively they total millions of dollars to the entire state, and individually they appreciably reduce the farmers' margin of profits.

The loss due to smut in any particular field is not difficult to estimate. Generally speaking, a diseased plant does not produce seed or grain, hence the reduction in yield for any field can be estimated by the percentage of diseased plants which it contains. The degree of loss, however, varies according to the crop, season, and market conditions.

In 1914 the Kansas State Board of Agriculture estimated the value of the various cereal and forage crops as follows:

Crop.	Yield.	Value.
Winter wheat, bushels	180,375,042	$151,143,794.94
Corn, bushels	87,338,272	59,320,146.75
Oats, bushels	45,348,857	17,780,294.58
Barley, bushels	4,355,565	2,024,351.73
Kafir, tons	3,438,632	15,710,644.00
Broom corn, pounds	12,249,150	401,510.77
Millet, bushels	222,762	1,207,658.50
Rye, bushels	2,193,279	1,562,877.96

The conditions which enter into the estimation of losses are numerous, and up to the present time it is impossible definitely to estimate the injury due to smuts among the various cereal crops of the state. From observations and correspondence concerning the losses of the past season, together with data furnished on good authority, the following figures seem conservative estimates of the damage caused by smut diseases in Kansas in 1914.

Injury from stinking smut in wheat varies greatly, fields in Kansas having been observed to range from 1 to 20 percent, while 50 percent or more of damage has been observed in fields in the United States. The loose smut of wheat, although not as abundant in Kansas, is also by no means uncommon. These two smuts combined probably caused a loss of $3,022,875 in 1914, estimating the damage at 2 percent.

Injury from corn smut is more difficult to determine on account of the various methods of attack. Not only is the grain itself smutted, but the plant as a whole is affected, thereby reducing its yielding capacity. In the first annual report of this station it was shown that this disease reduces the grain-yielding capacity of the plant about one-third. The number of plants affected with corn smut, on an average, will run about 15 percent in this state, hence the actual loss would approximate about 5 percent of the crop, or $3,000,000.

Oat smut was prevalent in Kansas in 1914. The damage varied from 1 to 20 percent in different fields, but the average loss has been estimated by good authority as being 8 percent for the United States. Investigations in other years show that different fields in this state contain anywhere from 1 to 39 percent of smut. Using 8 percent as a basis, a loss of $1,422,423 was sustained last year.

Barley smut likewise was prevalent in 1914. Both the loose and covered smuts of barley occur in Kansas, and for 1914 it is estimated that a combined damage of 4 percent occurred. Using this as a basis, a loss of $80,974 was brought about.

In 1912 the value of the kafir crop for Kansas for forage and feed was $19,635,000. The loss produced by smut was then estimated at 10 percent of the grain crop, but since the grain furnishes only one-half the value of the crop, the damage for that year reached a figure of $1,000,000. Placing the loss last year (1914) at 5 percent, its equivalent amounts to $392,766.

Broom corn is affected by the same smuts that attack the other sorghums. The greatest injury is done by the kernel smut, which has a singular effect in that the seed is not only destroyed, but the disease also affects the brush, discoloring it and causing a central stem to appear in the heads attacked. A brush of this type is of very inferior quality. The loss commonly amounts to 10 percent or more, but using a very con-

servative estimate of average loss, 3 percent, an equivalent of $12,045 damage occurred in this state in 1914.

Few data are at hand upon which to base estimates on the loss produced by millet smut, but at 1 percent it would amount to over $12,076.

While three different kinds of smut are known to attack rye, only two are found in the United States, and if they occur in Kansas they are not now present in sufficient quantities to be of economic importance.

The foregoing figures are considered quite conservative, and it is probable that the losses exceed the figures given. Yet, using these figures, a total of $7,943,159 represents the loss due to the smut diseases alone in Kansas in 1914.

Crop.	Smut.	Percent damage.	Loss.
Wheat	Stinking and loose smut	2	$3,022,875
Corn	Corn smut	5	3,000,000
Oats	Oat smut	8	1,422,423
Barley	Covered and loose smut	4	80,974
Kafir	Kernel smut	5	392,766
Broom corn	Kernel smut	3	12,045
Millet	Kernel smut	1	12,076
Total			$7,943,159

Cause of Smut Diseases.

Smut diseases are brought about by minute parasitic plants, known as fungi. As a rule they enter the plant either by getting into the young developing ovary during the flowering stage, or else they gain entrance to the plant in the seedling stage and develop within the tissues of their hosts. As long as the fungus remains within the tissues there is nothing externally visible by which its presence can be detected. Hence it is impossible to determine from outside appearances whether a plant is infected until it approaches heading time. When this stage is reached the diseased individuals can readily be noticed. As the plants mature and begin to form seed those affected produce heads or seeds which have been transformed into a more or less black, powdery dust. This black, sooty, powdery mass, which is characteristic of this group of fungi, is composed of an infinite number of microscopic reproductive bodies of the fungus, known as "spores." These little bodies perpetuate the disease from year to year, either by clinging to

the outside of the seed and infecting the seedling when the seed germinates, or by infecting the interior of the seed ("germ") at the outset.

The various smut diseases of plants are caused by different kinds or species of smuts. They affect the cereals and other plants in various ways, but each different smut disease is produced by a specific fungus. For example, the spores of the stinking smut of wheat can not produce the loose smut of wheat or the smuts of barley. A given smut fungus will cause only its own specific disease. Clean wheat seed could, therefore, be contaminated with oat smut spores, but would not take the oat smut disease, and wheat smut would not result from such a contamination.

It should be noted here, however, that a number of Kansas crops which are quite distinct from the farmer's point of view are botanically closely related. These comprise the general group known as the sorghums, and include kafir, feterita, kaoliang, broom corn, Jerusalem corn, milo, Sudan grass, and cane. The kinds of smut attacking kafir, therefore, also occur on all the other sorghums, with the exception of milo, which is immune.

Although the cereal smuts resemble one another in their life habits, there are some important differences which make it necessary to follow somewhat different methods for prevention. The various treatments are explained in detail on page 26.

The Three Groups of Smut.

Since there are ten important smut diseases in Kansas, it becomes necessary to group them according to their life habits, so as to simplify what is known regarding their mode of living and intensify our knowledge pertaining to their control. Smut diseases may be placed in one of three classes or groups, based on their life cycle. (See summary.) These groups, with the smuts included therein, may be described as follows:

GROUP 1.—*Corn Smut and Head Smut of the Sorghums.*

The smuts of this group can not be controlled by treating the seed. The spores which cause and perpetuate these diseases are not necessarily carried on the outside of the seed. Corn smut and the head smut of sorghum belong in this group.

Infection results from the spores which live and winter

over in the soil, or in manure which has become contaminated with smut spores. There is this difference, however, in life habits between the corn smut and the head smut of sorghum. In the case of the corn smut, so far as is known, most of the infection appears to be due to secondary spores, which, carried by the wind, alight on the young corn plants, causing local infection. Later a smut boil develops wherever infection has occurred. In the case of the head smut of sorghum, the fungus gets into the seedling directly from the soil, and in that way alone causes infection. It is never carried to the aërial parts of the plant, as appears generally to be the case in corn smut. Once inside the sorghum seedling, the head smut fungus grows within the tissues and keeps pace with their development. No evidence of its presence occurs, however, until the head protrudes from the sheath, when instead of a head of grain a smutted mass occurs.

Since the spores producing corn smut and the head smut of sorghum live over in the soil and in manure, it is useless to disinfect the surfaces of the corn or sorghum seed to combat these diseases.

GROUP 2.—*Kernel Smut of the Sorghums, Stinking Smut of Wheat, Smut of Oats, Covered Smut of Barley, and Smut of Millet.*

The smuts of this group have been thoroughly studied, and it has been found that they can be controlled by seed treatments, since the spores of the fungi causing these diseases cling to the outside of the grain. The kernel smut of the sorghums, the stinking smut of wheat, the smut of oats, the covered smut of barley and the smut of millet are examples occurring in this group.

The smut spores are scattered at harvesting time, chiefly in threshing, and are further disseminated by means of contaminated machinery, sacks, or bins. If contaminated seed is planted the following year, the adhering smut spores germinate simultaneously with the sprouting seed. The fungus penetrates the tissues of the grain plantlet, keeping pace with its growth until heading time approaches. Instead of producing a normal spike or head, a mass of smut or "smut balls" occurs in place of each kernel. The spores comprising these masses are scattered by various agencies, and cling to the out-

side of healthy seed. When this seed is planted the same series of events is repeated.

This group of smuts is controlled by disinfecting the surfaces of the seed.

GROUP 3.—*The Loose Smuts of Wheat and Barley.*

There are but two smuts in this group, namely, the loose smuts of wheat and barley. They also may be prevented by treating the seed, but by a special kind of treatment. The spores producing these diseases are not associated with the surface of the seed; that is, *the spores do not cling to the outside of the seed, but infection exists inside the "germ" or embryo of the seed.*

When the heads emerge from the "boot" in wheat and barley, one may notice the first indications of loose smut. In place of seed formation, a loose, powdery mass of spores develops. These spore masses are soon scattered, leaving the naked stems of the heads remaining. The spores are carried to neighboring healthy plants, which are in full bloom at this time. If they alight on the ovary of the flower, at just the right stage, they germinate, penetrate it, and infect the "germ" of the growing seed. After infection has resulted, the fungus goes into a resting stage and remains quiescent. The seed, however, continues to grow, and develops into a normal "berry," although it is *internally* infected with the loose smut fungus. If this seed is planted the next year without special treatment, the plant developing therefrom will be affected with the loose smut, for the fungus is *inside* the "germ" of the seed, and will grow inside the developing plant until it reaches maturity. It is thus seen that the production of a plant affected with loose smut really requires two seasons from the time when infection occurs.

A table giving the common names and control measures for the various smuts occurring in Kansas is found in the summary.

The Characteristics of the Different Smuts.

CORN SMUT.

CORN SMUT—*Ustilago zeæ* (Beck.) Ung.—is usually found on the tassel, ear, lower ear buds, or at the nodes of the plant. Occasionally it will also be found on the stem and leaves. (Figures 1 to 4.) In the early stages the excrescences, or smut

masses, are white and covered with a thin membrane, which at certain stages has a silvery lustre. (Figure 3.) As the smut mass matures it becomes black, and the surrounding membrane ruptures. These masses contain millions of spores, and are scattered by the wind and rain. They fall to the soil, and also get into the manure from infested corn fodder which

FIGURE 1.—Corn smut on tassel.

has been fed to stock. The spores withstand extremes of weather conditions, such as freezing and drying, and may even pass through the alimentary tract of animals without losing their vitality. Old cornstalks, contaminated manure, etc., generally contain a large number of smut spores, and when this is incorporated into the soil the corn smut disease is perpetuated from year to year.

There is no satisfactory method of control. It is possible

at times, but not generally practicable, to reduce the amount of corn smut by cutting out the smut masses as soon as they appear and before they become black. All such material should be burned, and not thrown on the ground, for the smut masses may ripen even if removed from the corn plant. If land is not planted to corn more than once in every third year the loss from smut appears to be less. Some varieties

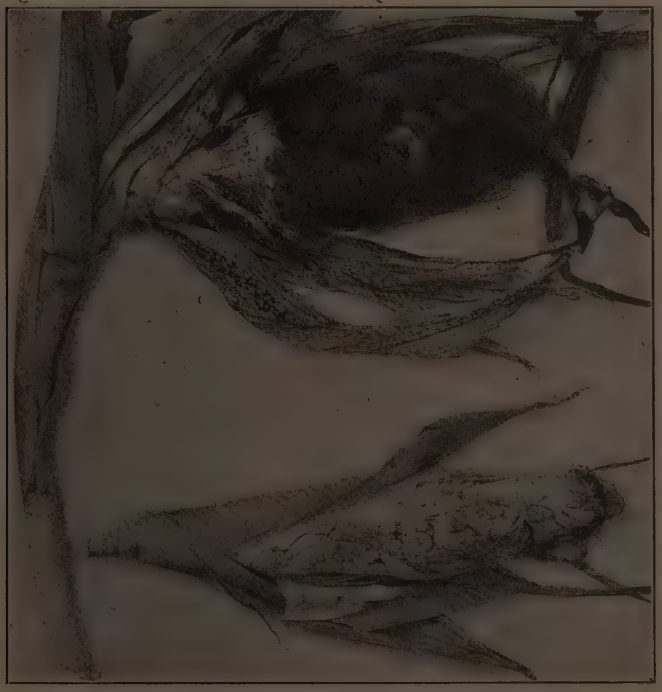

FIGURE 2.—Corn smut on ear.

apparently are more susceptible to corn smut than others, but none are immune. Kansas Sunflower is perhaps one of the less susceptible varieties commonly grown in this state.

SMUTS OF THE SORGHUMS.

Up to 1891 the sorghum smuts were uncommon in Kansas, but since then they have been steadily increasing. Those who have grown kafir, sweet sorghum, broom corn, shallu, or kaoliang, have undoubtedly seen sorghum smut.

There are two principal species or kinds of sorghum smut found in this state, namely, the kernel smut, and the so-called head smut. (Figures 5 and 11.) The former is the more common and destructive in Kansas.

One may have noticed that milo is not included in the list of susceptible hosts. Peculiar as it may appear, milo, sometimes classified with the durra group, is immune to both the

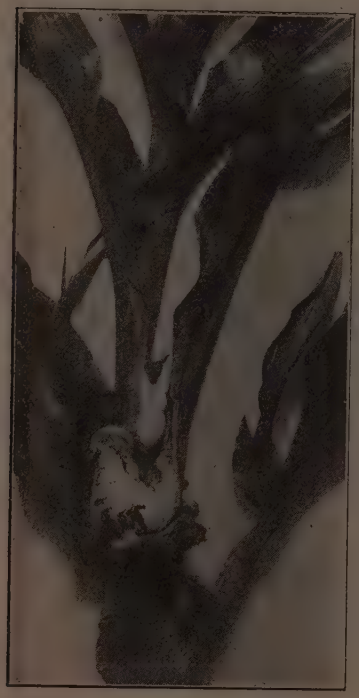

FIGURE 3.—Corn smut boil, showing the silvery membrane.

FIGURE 4.—Corn smut on sheath.

sorghum smuts. The durra group of sorghums, comprising feterita, Jerusalem corn and brown durra, while not immune, have been found in commercial culture to be affected less than the kafir or the sorgos (sweet sorghum). There are indications that the various kafirs show a difference in degree of susceptibility to kernel smut, but sufficient evidence is not at hand to make definite statements concerning varieties. Kaoliangs are

FIGURE 5.—Kernel smut on Black Amber. *A*, diseased head. *B*, healthy head. The diseased head shows the grayish color and conical form of the false kernels.

apparently peculiarly susceptible to sorghum smut, as are also the sorgos.

KERNEL SMUT OF KAFIR—*Sphacelotheca sorghi* (Lk.) Cl., and *Sphacelotheca cruenta* (Kühn.) Potter*—are noticeable

* This is the loose kernel smut of sorghum, recently shown to be botanically different from the ordinary kernel smut. For the purpose of this bulletin, however, they may be treated under one head.

when the sorghums begin to head. Close examination shows that affected heads bear a greater or less number of *false* kernels. These are composed of a mass of smut dust enclosed in a cone-like, grayish-brown, slightly toughened membrane. (Figures 6 and 7.) This breaks very readily in threshing, thereby liberating the enclosed spore masses. If one of the

FIGURE 6.—Kernel smut of sorghum. *C* and *D* are portions of a diseased head showing the false kernels. *E*, a portion of a healthy head.

false kernels is crushed between the fingers the black smut dust contained therein will be observed. The kernels are usually the only part of the head which is transformed into these masses of smut spores. This sorghum smut perpetuates itself from year to year by means of the spores which adhere to the sorghum seed. If such contaminated seed is planted without killing the adhering smut spores, the crop therefrom will be diseased with the kernel smut.

The method of control is either by the hot-water or the formaldehyde treatment. (Page 34.) It would pay to collect the seed while the plants are still standing in the field. Not only does this enable the grower to select clean seed, but it gives him the opportunity to select typical heads of sorghum. Such seed could be threshed by itself, thereby avoiding any chance for contamination. In such a case a seed treatment would not be required.

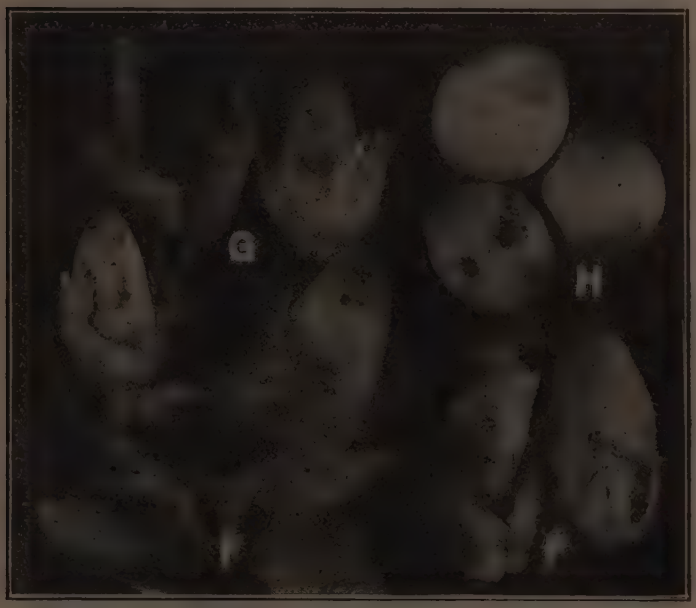

FIGURE 7.—False kernels of the sorghum kernel smut. *F*, showing the cone-like grayish-brown membranes surrounding the enclosed mass of smut spores. *G*, a false kernel with the membrane broken, showing the black mass of spores. *H*, healthy kernels of the same variety of kafir.

KERNEL SMUT OF SUDAN GRASS—*Sphacelotheca sorghi* (Lk.) Cl.—is the same as the other sorghum smuts, but special attention is called to it because Sudan grass is so new a forage crop in Kansas. Within the last year, the writer has reported kernel smut of Sudan grass from different sections of the state. It is like the kernel smut of kafir and other sorghums (figure 8), and is, in fact, caused by the same organism. Diseased plants do not produce as large panicles as normal

plants, and usually all the seed is replaced by *false* kernels. On this account, and wherever these crops are grown in the same vicinity, the kernel smut may be transferred from one crop to the other. The *false* kernels are about twice the size of normal seed, but quite unlike them in appearance. (Figures 9 and 10.) They are rather cylindrical in shape, being

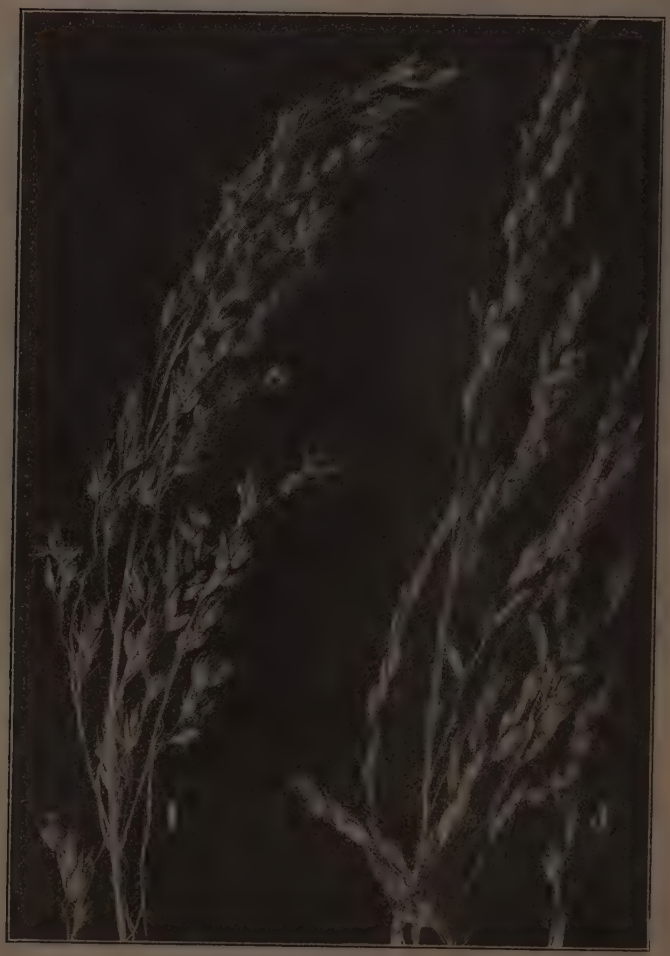

FIGURE 8.—*I*, head of Sudan grass affected with the kernel smut. Note the cone-like false kernels protruding, with the glumes spreading apart. *J*, healthy head of Sudan grass.

slightly larger at the base than at the top. The outer glumes remain normal, being spread apart by the spore masses, which are enclosed in a grayish membrane. When this membrane ruptures the spores are scattered the same as in the kernel smut of kafir. The kernel smut of Sudan grass will probably become widespread in Kansas, for it will become more prevalent each year as this crop increases in acreage.

Unpublished investigations of the writer have shown that the hot-water and formaldehyde treatments, similar to those

FIGURE 9.—Seed of Sudan grass. *K*, with glumes. *L*, without glumes. Compare with the false kernels, figure 10.

used for sorghum seed, will also control this disease when present in Sudan grass. (Page 34.)

HEAD SMUT OF SORGHUM—*Sphacelotheca reiliana* (Kühn.) Cl.—was unknown in this country previous to 1890, but it was reported in Europe and Africa some years earlier. The head smut of the sorghums is the least common of all the smuts occurring in this state. It is very different in appearance from the kernel smut. The entire head is involved, being transformed into a sooty mass of smut spores. Sometimes only a portion of the head is attacked. Diseased plants can be noticed as soon as the heads protrude from the sheath, as

a whitish membrane is present, which soon ruptures and disappears. The only evidence that a head of grain should have been present is found in the remnants of a few strands of vascular tissue intermingled with a large, black, sooty mass of spores. (Figure 11.) It occurs also on corn, but fortunately is not common in Kansas. The life habits are known, resembling somewhat in nature those of the common corn smut, in that the spores are scattered to the soil before harvesting, and remain alive over winter.

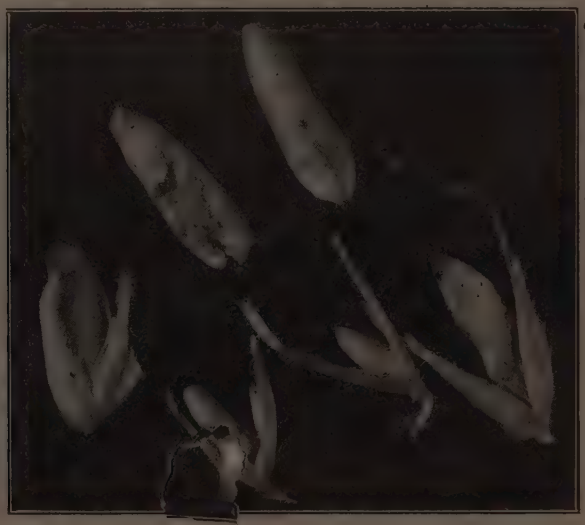

FIGURE 10.—Kernel smut of Sudan grass. Note the cone-like false kernels as they protrude from the glumes.

There is no satisfactory method of control, but since it is very rare in Kansas, no special stress need be laid on its treatment.

SMUTS OF OATS.

OAT SMUT—*Ustilago avenæ* (Pers.) Jens., and *Ustilago levis* (Kell. and Sw.) Magn.—as found in Kansas, is distinguished by the black masses of spores which replace the normal seeds. The smut can first be noticed as the panicles protrude from the "boots" of the plants. (Figure 12.) The grain, and sometimes the chaff, is replaced by this dusty mass, which may later be dispersed, leaving a more or less naked panicle. Gen-

erally all the heads of an affected plant are smutted. Diseased plants are oftentimes shorter and stockier, standing more erect than normal plants. The diseased plants often escape notice because they are dwarfed and inconspicuous, but they can readily be recognized in the field, even before the panicles protrude from the "boot," by the fact that the uppermost leaf of the diseased plant assumes a yellowish or reddish-yellow color.

FIGURE 11.—Head smut of kafir. Note the vascular strands, or fibre-like conducting vessels of the kafir stem, intermingled with the black mass of smut spore dust.

The formaldehyde and hot-water treatments are the methods of control. (Pages 35 and 36.)

SMUTS OF WHEAT.

THE STINKING SMUTS OF WHEAT—*Tilletia fœtens* (B. & C.) Trel., and *Tilletia tritici* (Bjerk.) Wint.—are usually considered as one disease by the farmer and are variously known

as covered smut, closed smut, bunt, or stinking smut. In this disease the spore masses are enclosed in a more or less brittle, grayish-brown membrane. These smut masses are somewhat enlarged or swollen, and are commonly called "smut balls." (Figure 13.) By comparing them to healthy kernels, one finds

FIGURE 12.—Smut of oats. Healthy head, and smutted heads in various stages.

that they are larger, lighter, and if viewed externally are generally grayish in color, with roughened or pitted surfaces. These smut masses are not scattered about by the wind, but are held within the membrane. If this is broken in threshing, however, the spores are scattered, and lodge in the brush and crease of the clean seed, thereby contaminating it.

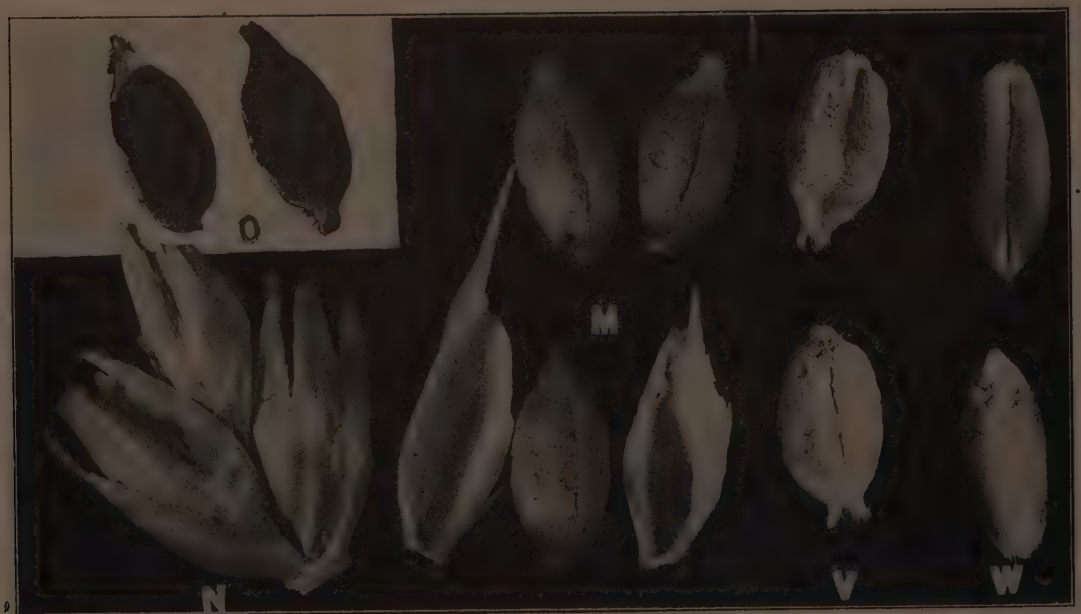

FIGURE 13.—"Smut balls" of stinking smut of wheat. *M*, smut balls as they occur when the glumes are removed. *N*—Note the natural outward appearance of the glumes as they surround the smut balls. *O*, a smut ball cut in two, disclosing the black mass of smut spores. *V*, smut balls greatly magnified. *W*, normal kernels of wheat magnified the same number of times.

The disease can not easily be recognized by casual examination of the spike or head of wheat alone. Externally it somewhat resembles a normal head (figure 14), being darker green when young, and when mature almost always shorter and somewhat darker in color, with the chaff spreading. Generally all the kernels in a head are attacked, and all the heads in a plant are diseased. Such heads have a fœtid odor, not unlike decayed fish, hence the common name, "stinking smut."

FIGURE 14.—Head of wheat affected by stinking smut. *T*, healthy head of wheat with normal kernels. *U*, diseased head with smut balls removed.

The loss due to the covered smut of wheat not only results from the damage to the grain itself, but the fœtid odor of the smut balls is such that a small quantity mixed with healthy seed is sufficient materially to reduce the grade of the wheat, and consequently its market value. The grain is indeed often unsalable, for it is valueless for flour making unless special scouring processes are used.

In some parts of the country serious explosions, due to the

presence of this smut dust, have occurred in separators during the threshing of badly smutted crops.

This disease is controlled either by the formaldehyde or hot-water treatment. (Page 35.)

THE LOOSE SMUT OF WHEAT—*Ustilago tritici* (Pers.) Jens. —is first apparent as the heading stage approaches. It is quite different from the stinking smut in that all the glumes or chaff, as well as the kernels, are transformed by the smut

FIGURE 15.—Loose smut of wheat.

fungus into a loose, dusty, olive-black mass of spores. (Figure 15.) These masses do not adhere very long to the wheat stems, but are blown about or removed by the rain, leaving only naked wheat stems. The heads are completely destroyed, for this smut usually attacks every spikelet on a head and every head in a plant. Although this disease is not as abundant in Kansas as the stinking smut, it is by no means uncommon, is widely distributed, and is apparently on the increase.

The treatment generally recommended for this disease is a special method, known as the modified hot-water treatment, or the long-time hot-water treatment. (Pages 33 and 37.)

KERNEL SMUT OF MILLET.

MILLET SMUT—*Ustilago crameri* Körn.—frequently becomes quite serious in millet-growing communities. It is a "kernel smut," the smut masses being enclosed in a membrane and replacing each kernel separately. When this membrane is broken in threshing, the spores are scattered and cling to the seed.

FIGURE 16.—Covered smut of barley. *P*, smutted heads. *Q*, healthy head, same variety.

The writer found a species of smut attacking the yellow foxtail grass (*Setaria glauca*) in Kansas in regions where millet is grown. This is apparently a closely related species to the one which attacks millet, and may be a source of infection and perpetuation of the disease on millet, although this point requires further investigation.

German millet seed is generally more or less contaminated with this smut. It is, therefore, better to secure seed which has been grown in this country, in a region where smut does

not occur. Where there is danger of contamination each season, seed treatment is advisable.

The hot-water or formaldehyde treatments are the methods of control advised in this country. (Page 36.)

Hog millet, or proso, is sometimes affected by a head smut concerning which but little is known.

FIGURE 17.—Loose smut of barley. *R*, healthy head of barley of the same variety as those affected with loose smut. *S*, diseased heads in various stages.

SMUTS OF BARLEY.

IN THE COVERED SMUT OF BARLEY—*Ustilago hordei* (Pers.) K. & S.—the smut masses replace the chaff and grain, and are contained within a grayish membrane. (Figure 16.) This is rather thin and transparent, and shows the greenish-black

spore mass contained therein. The spores are not scattered about by the wind and rain, unless the membrane is broken, which does not generally occur until threshing. This disease is generally later in its appearance than loose smut.

The formaldehyde and hot-water treatments are the means of control. (Page 36.)

THE LOOSE SMUT OF BARLEY—*Ustilago nuda* (Jens.) K. & S.—like the loose smut of wheat, is most noticeable as the heads emerge from the "boot." These smuts resemble each other not only in their appearance, but to some extent, at least, in their life habits and their manner of infection. The chaff and kernels are replaced by a dark, sooty mass of spores, which, viewed in a mass, are olive-brown in color and adhere loosely to the rachis or stem of the head. The mass is not enclosed in an enveloping membrane except in the early stages, and this soon ruptures and disappears. (Figure 17.) On account of this fact it is an easy matter for the spore masses to become dispersed by the wind and washed away by the rain. This smut appears about two weeks earlier than the covered smut of barley. Oftentimes the smutted heads are very noticeable in a field, since they are lighter than normal ones and remain erect. Before harvesting time arrives, smutted heads become bare stems, thus furnishing an indication that the loose smut of barley is present.

The modified hot-water treatment is the method of control usually recommended, but the long-time formaldehyde treatment* appears to be more promising. (Pages 33 and 37.)

Seed Treatment to Prevent Smuts.

The prevention of losses from smuts is a problem which confronts every Kansas farmer who is growing small grains or forage crops. The old proverb, "An ounce of prevention is better than a pound of cure," applies here, since cures of infected plants are either impracticable or impossible.

Most of the smuts can be avoided by treating the seed; therefore the smut-disease problem is entirely one of prevention. Proper treatment of seed before planting is the prin-

* Recent unpublished investigations by the Office of Cereal Investigations, United States Department of Agriculture, show that certain seed-borne diseases, such as the loose smut of barley, are at least partially controlled by a long-time formaldehyde treatment.

cipal means of reducing the annual losses brought about by these plant diseases.

The most common treatments which are employed for reducing smut are: (1) The formaldehyde ("formalin") treatment; (2) the hot-water treatment; (3) the bluestone, or copper sulphate treatment; (4) the modified hot-water treatment.

THE FORMALDEHYDE SEED TREATMENT.

Ever since formaldehyde ("formalin") came into use as a germicide, a little over a quarter of a century ago, its value as a fungicide has been steadily gaining favor, until to-day it is one of the most common and effective chemicals used for seed treatment. Formaldehyde ("formalin" is the commercial term for a 37 percent solution) is a gas dissolved in water, which has a strong, penetrating odor and biting taste. It may be bought from any wholesale drug company or chemical supply store. The cost will depend upon the quantity purchased. In buying less than a gallon, the price per pint (a pint is equivalent, approximately, to one pound) is about fifty cents, but in purchasing larger quantities it may be bought for eleven cents a pint. In buying formaldehyde one should be certain that it is guaranteed 37 percent strength (generally said to be 40 percent). If in doubt a sample should be submitted to a chemist for analysis.

Solutions which have been used for treating seed may be used several times, but if they have stood exposed to the air for longer than twelve hours they should not be used. It is better to mix fresh solutions, for chemical analyses show that formaldehyde solutions gain strength upon standing.

The formaldehyde seed treatment was first used as a preventive for oat smut, but it is now likewise used to prevent the kernel smut of sorghums, the bunt of wheat, the covered smut of barley, and the smut of millet. It may also prove to be a practical treatment for the loose smut of barley.

The apparatus necessary for the formaldehyde seed treatment for the various smuts just mentioned is very similar. The chief difference is in the strength of the formaldehyde solution used for treating the seed, and the length of time that the seed remains therein.

Large vats, tanks, tubs or barrels which will hold from

thirty to fifty gallons are necessary. In addition to these, wire baskets having a capacity of half a bushel, coarse sacks (gunny sacks), a supply of water and commercial formaldehyde are the essential things required. The formaldehyde treatment will not materially injure the vitality of good seed, if the treatment is carefully performed according to directions.

This treatment may be given in any one of three different modes of application, depending upon which of the cereal smuts is concerned. These are: (1) The dipping method; (2) the immersion method; (3) the sprinkling method.

THE DIPPING METHOD. The solution is made by mixing the stipulated amounts of formaldehyde and water in a suitable tank or barrel. The seed to be treated is placed in coarse sacks and plunged into the solution for a moment, allowed to drain, and the process is then repeated, with agitation, until it is certain that all the grain has been thoroughly wet. The length of time generally varies from five or ten minutes to one or two hours, depending upon the kind of seed. Allow more than sufficient room in the sacks for the swelling of the seed.

At the end of the stated time the sacks with their contents should be removed and drained. The seed should be spread out in thin layers on a clean floor or canvas, free from smut contamination, and allowed to dry. The seed may be sown immediately after drying, or it may be stored.

THE IMMERSION METHOD. It becomes necessary to use this method when smut balls and smutted chaff are present in the wheat seed. Very elaborate machines are on the market which are used in carrying out this process, but simple, inexpensive, home-made devices may be constructed which will accomplish the desired result.

A very convenient outfit for carrying out the immersion method, which provides for smut-ball removal, is as follows: Two wooden tubs, or a large barrel cut in two, are secured. A hole is bored in the side towards the bottom of the tub, and plugs are provided for these openings. Pieces of screen are tacked on the inside of the tub over these openings, so that the grain can not pass out. Then one tub is placed above the other as shown in figure 18. The upper tub is filled about two-thirds full with the formaldehyde solution (one pint formaldehyde to forty-five gallons of water), the seed to be treated

poured in and stirred. This causes the chaff, smut balls, and light kernels to float, and the refuse is then skimmed off. After the seed has soaked in this solution for ten or fifteen minutes the plug may be removed and the solution allowed to drain into the tub below. The grain should then be spread out and dried, taking the necessary precautions to prevent contamination. (Page 30.) The position of the tubs may then be reversed and the process repeated, using another lot of seed.

The principle which has been described herein may be applied in constructing large tanks or vats, designed to carry out the immersion method on a more extensive scale.

FIGURE 18.—A barrel cut in half, furnishing two tubs. These provide a device for smut-ball removal.

THE SPRINKLING METHOD. Where large quantities of wheat or oats are to be treated, the sprinkling method is much quicker and more easily performed. The grain should be spread out in a layer from four to six inches deep, and the solution, made by mixing the stipulated amounts of formaldehyde and water, applied by means of a sprinkling can. One gallon of the solution is sufficient for treating approximately one and one-third bushels of grain. One man should sprinkle the seed while another shovels it over, as in mixing concrete. Every kernel should be uniformly moistened. The seed should then be placed in piles and covered with clean sacking,

blankets or canvas, and allowed to stand two hours, six hours, or overnight, according to the kind of seed, after which it should be spread out and thoroughly dried.

GENERAL PRECAUTIONS. In order to eliminate all possibilities of contamination, new sacks should be used for storing the seed, or the sacks which have been used previously should be soaked for a period of two hours in the solution employed for treating the seed for smut. It is advisable to sprinkle the floor

FIGURE 19.—Barrels arranged for the hot-water method of seed treatment. *I*, tempering bath. *II*, treating bath. *III*, cold-water supply. *A*, shut-off valves. *b*, rubber hose.

with a strong solution of formaldehyde before spreading the seed to dry. Care should be taken that bins and drills are free from smut spores, by sterilizing them through washing with a strong solution of formaldehyde. It is sometimes claimed that formaldehdye solutions, when mixed with water, are most effective at temperatures of 50°-70° F.

The germination of treated seed should be tested, and if the germination is low the rate of planting should be proportionately increased.

Precautions against freezing or sprouting after the treatments should be taken.

THE HOT-WATER SEED TREATMENT.

This method may be used instead of the formaldehyde treatment for the stinking smut of wheat, covered smut of barley, smut of oats, kernel smut of sorghum, and smut of millet. The temperature of the hot water and the length of treatment varies according to the kind of grain treated.

The hot-water treatment is effective and easily carried out if steam is accessible. A small steam boiler or traction engine provides the ideal means for applying the hot-water treatment

FIGURE 20.—Sack-basket which is used for the hot-water treatment of the grain.

or the modified hot-water treatment to be described. Unless steam is available the hot-water methods are rather difficult to carry out effectively, since steam is preferable to an open fire* for heating the water.

* Seed-treating stations can readily be established in communities where creameries or elevators are located.

The necessary apparatus is as follows: Three large barrels (vinegar, oil or molasses barrels) or tanks, several sack-baskets,* two accurate Fahrenheit dairy thermometers,† and steam or open fire for heating the water.

For convenience in describing the hot-water method, the barrels will be numbered 1, 2 and 3. Barrel 1 is known as the tempering bath, barrel 2 as the treating bath, and barrel 3 as the cold-water dip.

Two half-inch pipes should be run from the main steam pipe to a place directly above barrels 1 and 2. It is best to attach pieces of hose, which should lead into the barrels, to the ends of the half-inch pipes. This gives flexibility, and the hose may be easily taken out of the barrels if necessary. Shut-off valves should be provided at *A* (figure 19). By means of these the volume of steam can be regulated, thereby heating the water to the desired temperature. The entire process can be carried out by one man.

The seed to be treated should be placed in coarse sacks, sack-baskets or wire baskets. Not more than a half bushel of seed should be treated at one time, and more than sufficient room should be allowed in the sacks for the swelling of the seed. The sacks containing the seed are first dipped into barrel 1 (tempering bath) for a moment. This will raise the temperature of the seed to a few degrees below the temperature of the water in barrel 2 (treating bath), thereby preventing the temperature of the latter from being lowered when the sacks of seed are placed therein. The temperatures must be carefully regulated according to the directions specified for the different smuts. Cold water may be added if the temperatures approach the danger mark. At the end of the stated time the sacks should be removed and the grain spread out in thin layers on a clean place and allowed to dry. If the seed is not immediately spread out it should be plunged into barrel 3 (cold-water dip) for a few minutes.

HOT-WATER TREATMENT WITHOUT ACCESS TO STEAM.

As previously stated, the most effective and accurate method of applying the hot-water treatment on a large scale is by means of steam. However, by careful manipulations it is possi-

* Sack-baskets are especially adapted for treating wheat which contains smut balls. They are made by cutting off about one and one-half feet from the top of an ordinary gunny sack, and sewing a three-eighths-inch iron hoop into the opening of the sack. This makes a permeable basket. By means of ropes or heavy wire, handles may be made. (Figure 20.)

† All temperatures herein given are expressed in terms of the Fahrenheit thermometer.

ble to treat seed for smut by means of the hot-water methods, even though steam is not available. The process is the same as already described, but it is necessary to make provisions for heating the water. A supply of cold water is also necessary. The temperature of the treating bath is regulated by adding hot or cold water as required. The larger the barrels or vats the easier it is to regulate the temperature of the water.

THE MODIFIED HOT-WATER SEED TREATMENT.

Although this method has been used to some extent it has some objectionable features, which not only make it impracticable, but nondependable. Those who wish further information concerning this treatment are referred to Farmers' Bulletin 507, United States Department of Agriculture, or to the Department of Botany, Agricultural Experiment Station, Manhattan, Kan., which will furnish the desired information.

The modified hot-water seed treatment is designed for the loose smuts of wheat and barley. The essential features of the treatment consist in soaking the seed from four to six hours in water at room temperature, followed by immersion in hot water at temperatures and for periods of time varying with the kind of seed to be treated.

It might be stated that a long-time formaldehyde immersion method has been recently discovered, which is at least partially effective in controlling the loose smut of barley. For this, however, the seed should be soaked for not less than two hours in a solution made by mixing one pint of formaldehyde with forty gallons of water. (Page 37.)

THE BLUESTONE SEED TREATMENT.

In some regions of the United States the bluestone treatment is still popular.

The method of procedure is as follows: A strong solution of copper sulphate is made by dissolving one pound of copper sulphate (blue vitriol) in four gallons of water, and the grain to be treated is placed therein for a moment. It is then removed and dried. The same apparatus is used as described for the formaldehyde treatment, which provides for smut-ball removal. (Page 28.)

Another method is to dissolve one pound of blue vitriol in twenty-five gallons of water, allowing the seed to soak for twelve hours with occasional stirring. After soaking, the seed

should be removed and placed in a milk-of-lime solution for five or ten minutes. This solution is made by slaking one pound of stone lime into a putty, and then adding ten gallons of water to make the milk of lime. After the seed has passed through these two solutions a film of copper compounds is deposited on the seed coats. In reality it is a kind of Bordeaux mixture.

The main objection to the bluestone treatment is that it may injure the seed to some extent. The solution soaks into the seed, and if the latter has been mechanically injured in threshing, its germination will be affected.

Oats and barley in particular are seriously injured by this treatment, and it must, therefore, never be used for these grains.

Seed Treatments for the Different Crops.

TREATMENTS FOR THE KERNEL SMUT OF THE SORGHUMS.

Formaldehyde Treatment.

Solution: One pint of formaldehyde to thirty gallons of water.
Time: One hour.

DIPPING METHOD. The process and equipment necessary is described on page 28. Some varieties of sorghums have glumes which tend to make the seeds float. It becomes necessary, therefore, to place a weight in the sack with the seed, so as to cause the sacks to sink. The formaldehyde treatment will not materially injure the vitality of good seed if the treatment is carefully performed according to directions. Seed which is cracked or otherwise mechanically injured in threshing is quite liable to be injured during treatment. Furthermore, varieties which do not retain the glumes on the seed are more susceptible to injury.

Hot-water Treatment.

Hot water: Between 134 and 140 degrees.
Time: Twelve minutes.

The process and equipment necessary is described on page 31. The temperature of the tempering bath (barrel 1) should be 120 degrees. The hot-water treatment is less liable to injure Sudan-grass seed. It is, therefore, perhaps better to employ this method for this particular sorghum.

Attention is called to the general precautions on page 30.

SEED TREATMENT FOR THE STINKING SMUT OF WHEAT.

Formaldehyde Treatment.

Solution: One pint formaldehyde to forty-five gallons of water.

IMMERSION OR SPRINKLING METHODS. The formaldehyde treatment for the control of the stinking smut of wheat may be given either by the immersion or by the sprinkling method.

Immersion method. (See page 28.) The seed should be allowed to soak ten or fifteen minutes.

Sprinkling method. (See page 29.) This treatment is only effective if the seed is free of smut balls. Therefore, all seed should be fanned previous to the formaldehyde treatment. Treated seed should remain covered for six hours or over night, using sacking or canvas free from smut spores.

Hot-water Treatment.

Hot water: Between 132 and 133 degrees.

Time: From ten to fifteen minutes.

The process and equipment necessary is described on page 31. The temperature of barrel 1 is 120 degrees, and of barrel 2, 132 to 133 degrees. For stinking smut of wheat it is best to use sack-baskets (see footnote, page 32) or wire baskets with open tops, instead of sacks which are tied shut. This allows the smut balls and chaff to float off.*

The temperature should not be allowed to rise above 135 degrees nor fall below 130 degrees.

Attention is called to the general precautions on page 30.

Bluestone Treatment.

This has been described on page 33. Attention is called to the general precautions, page 30.

SEED TREATMENT FOR THE SMUT OF OATS.

Formaldehyde Treatment.

Solution: One pint of formaldehyde to forty-five gallons of water.

Dip the seed until thoroughly wet, then remove from solution, and allow to stand half an hour, or:

Sprinkle, cover with canvas, and allow to stand for two hours.

DIPPING METHOD. The directions stated on page 28 should be followed. After the sacks are removed from the solution they should be set aside for half an hour, after which the seed

* Another way in which refuse may be removed is by placing the seed in a tub or vat containing water, stirring the seed, and skimming off the refuse, after which the seed may be placed in sacks and treated by the hot-water method.

should be spread out in thin layers and dried. Merely wet the seed thoroughly, and then remove from the solution.

SPRINKLING METHOD. This process and equipment has been described on page 29. The seed should stand covered for at least two hours, after which it may be spread out to dry.

Hot-water Treatment.

Hot water: Between 132 and 133 degrees.
Time: From ten to fifteen minutes.

This method has been described on page 31. The temperature of the water in barrel 1 should be 120 degrees, and that of barrel 2, 132 to 133 degrees.

Attention is called to the general precautions on page 30.

TREATMENT FOR THE COVERED SMUT OF BARLEY.

Formaldehyde Treatment.

Solution: One pint of formaldehyde to forty gallons of water.
Time: Two hours.

DIPPING METHOD. Follow directions as stated on page 28. It is advisable to allow the seed to remain in the formaldehyde solution for about two hours before it is spread out to dry. This is a long-time formaldehyde treatment. See note on loose smut control, page 37.

Hot-water Treatment.

Hot water: Between 126 and 129 degrees.
Time: Thirteen minutes.

The process and equipment has been described on page 31. Barley is perhaps a little more susceptible to injury with the hot-water treatment than wheat or oats; therefore it is treated at a slightly lower temperature. The temperature of the treating bath (barrel 2) should not be allowed to rise above 129 degrees. The temperature of the tempering bath is 120 degrees.

The formaldehyde treatment is perhaps even a little more efficient, and it is therefore recommended in preference to the hot-water method.

Attention is called to the general precautions on page 30.

SEED TREATMENTS FOR THE SMUT OF MILLET.

Formaldehyde Treatment.

Solution: One pint formaldehyde to forty-five gallons of water.
Time: Two hours.

DIPPING METHOD. The process and equipment necessary

has been described on page 28. The seed should remain in the solution two hours, after which it is spread out and dried.

Hot-water Treatment.

Hot water: Between 132 and 133 degrees.
Time: Ten to fifteen minutes.

The process and equipment necessary has been described on page 31.

Attention is called to the general precautions on page 30. The temperature of the tempering bath should be 120 degrees.

TREATMENT FOR THE LOOSE SMUTS OF WHEAT AND BARLEY.

Mention has already been made of the treatment for these diseases on pages 23 and 26. The method in present use, the modified hot-water treatment, is rather laborious and is somewhat difficult to carry out effectively on a large scale. Those interested are referred to Farmers' Bulletin 507, United States Department of Agriculture, or if inquiries are sent to this station detailed directions will be given.

What is known as the "long-time hot-water treatment" to prevent loose smut of wheat is perhaps more effective, all things considered. The seed is placed in sacks and dipped in water at from 110 to 115 degrees. All of the seed should be thoroughly wet. Frequent agitation is necessary. After remaining in this hot-water bath for three hours, with the temperature constantly between 110 and 115 degrees, the seed is removed and spread out to dry.

The loose smut of barley, as shown by recent investigations, is controlled to a considerable extent by a long-time treatment in a formaldehyde solution. The seed is placed in sacks and soaked in a solution of formaldehyde, made by mixing one pint of formaldehyde with forty gallons of water. The seed must remain in this solution for at least two hours, after which it is spread out and dried.

The Necessity of a Seed Plot.

One of the most important features in connection with loose-smut control is the maintenance of a seed plot. Where wheat and other small grains are grown in large quantities it is oftentimes impossible to treat all the seed. Especially is this the case where the modified hot-water treatment is necessary.

If a seed plot is maintained on a farm it will greatly aid the farmer in overcoming the loose-smut ravages.

In starting such a plot the seed should first be carefully selected, cleaned by means of fanning, and given the modified hot-water treatment, or the long-time hot-water or long-time formaldehyde treatments.

The selection of the plot is a very important matter. It should be located on a piece of land which is large enough to produce twice as much seed as will be required for planting the following year. This will allow for loss in cleaning and selecting. The seed plot must not adjoin a field planted to the same crop, as infection will result at flowering time. (Page 9.) This plot should furthermore be so located that the prevailing winds will not carry infection from near-by fields. An isolated spot in some woodland, cornfield or large meadow is most desirable.

The importance of these precautions can not be too strongly emphasized. Coöperation among the farmers will greatly aid in making this a success.

The seed plot should be maintained every year. Enough seed should be retained to plant the seed plot the following year, treating the seed regularly until the plot is clean. After this the treatment may be omitted as long as the seed plot is free from smut. Not only can the loose smuts be eradicated from the farm in this way, but an opportunity is also afforded for growing an extra good strain of seed.

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